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08 June 2001 (08.06.01)

Applicant

RENISHAW PLC et al

The International Bureau transmits herewith the following documents and number thereof:

_____ copy(ies) of declaration(s) (Rule 47.1(a-ter))

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 476W0	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 01/02616	International filing date (day/month/year) 08/06/2001	(Earliest) Priority Date (day/month/year) 08/06/2000
Applicant RENISHAW PLC		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the abstract,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

1
☐ None of the figures.

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(74) Agent: **WAITE, John**; Renishaw plc, Patent Department, New Mills, Wotton-under-Edge, Gloucestershire GL12 8JR (GB).

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— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

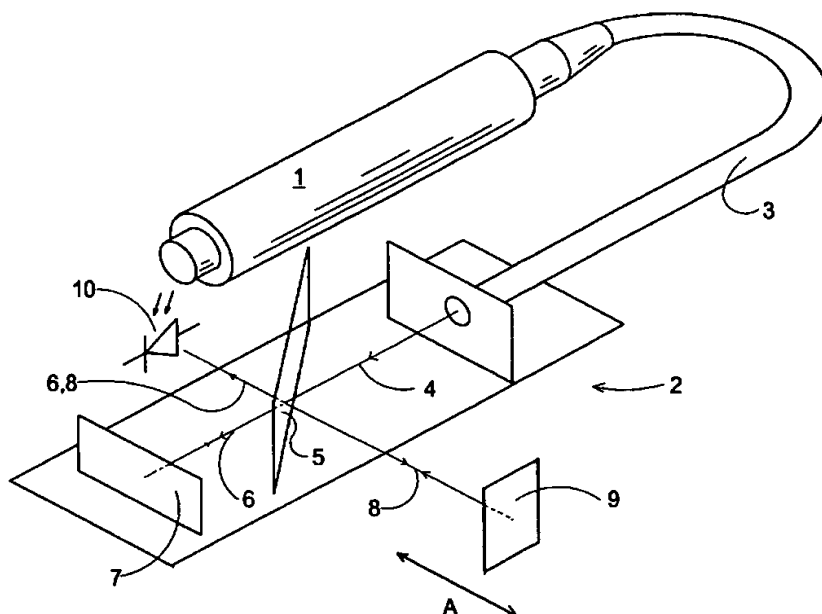
(71) Applicant (*for all designated States except US*): **RENISHAW PLC** [GB/GB]; New Mills, Wotton-under-Edge, Gloucestershire GL12 8JR (GB).

(72) Inventor; and

(75) Inventor/Applicant (*for US only*): **PRATT, Roland, Henry** [GB/GB]; 27 Sydenham Hill, Cotham, Bristol BS6 5SL (GB).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **GAS LASER AND OPTICAL SYSTEM**



(57) Abstract: An optical apparatus e.g. an interferometric displacement determination device; spectroscopic analysis apparatus; polarisation measurement apparatus; or a heterodyne frequency measurement device has a linear HeNe gas laser having a Ne content of an Ne²⁰ isotope and an Ne²² isotope in substantially equal proportions, the apparatus in use having optical feedback toward the laser causing, 0.1 % or more of the light output of the laser to be returned toward the laser (1). Use of this type of laser provides good polarisation stability even though excessive backreflection may occur, and hence the laser's frequency can be readily controlled.

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GAS LASER AND OPTICAL SYSTEM

The invention relates to a Helium-Neon gas laser and an optical system used therewith.

5 Typically gas lasers are used in apparatus which rely on the specific frequency of the laser light, for example light having a known wavelength can be used for interferometric measurement. Laser light at a specific
10 frequency is used as a reference to measure the frequency of other light for example in heterodyne frequency measurement systems. Laser spectroscopy requires a light of narrowly defined frequency also. Laser light of a specific polarisation and frequency
15 can be used for polarisation measurement.

Helium-Neon (HeNe) lasers are well suited to these applications since they produce a convenient frequency and are readily controllable.

20 Laser interferometers are shown in Patent Nos. WO98/05955 and US 4,844,593. One subject discussed in these documents is the prevention or reduction of laser output light being reflected back toward the laser
25 (known as "optical feedback" or "back-reflection"). The amount of back-reflection can be determined from known optical parameters of the optical elements used. However, only a small proportion of back-reflected light reaches the laser cavity i.e. approximately 1 to
30 5 hundredths of the back-reflected light.

Back-reflection is undesirable in the devices mentioned above and in all devices which require a specific frequency of laser light, because excessive back-

reflection interacts with the laser to change the polarisation and output frequency of the laser light. Various HeNe lasers suffer from sensitivity to back-reflection.

5

HeNe lasers having gas mixes of varying proportions are known. US Patent No. 4,475,199 describes a ring laser having a HeNe mix consisting of dual isotopes of Ne^{20} and Ne^{22} . Equal proportions of these two isotopes are
10 mixed with the He. It has now been recognised by the inventor that this mixture when used in a linear laser gives good polarisation stability and hence frequency stability in the resonant cavity of the laser when subjected to back-reflections. Therefore a laser of
15 this type is ideal for use in back-reflective situations encountered in the devices described above.

According to a first aspect of the invention there is provided an optical apparatus comprising a frequency
20 stabilised linear HeNe gas laser having an Ne content of an Ne^{20} isotope and an Ne^{22} isotope in substantially equal proportions, the apparatus in use having optical feedback toward the laser causing at least 0.1% of the light output of the laser to be returned toward the
25 laser.

The optical apparatus may be for example an interferometric displacement determination device; a polarisation measurement device; spectroscopic analysis
30 apparatus; or a heterodyne frequency measurement device.

Where the optical apparatus is an interferometric displacement determination device, the device may be

any one of a single beam (e.g. Fabry-Perot), a plane mirror, a long range, or an optical fibre type.

The Figure illustrates one embodiment of the invention and shows a plane mirror interferometer including an optical fibre.

The Figure shows a HeNe laser 1 used to provide constant frequency coherent light to an interferometric measurement apparatus 2 via an optical fibre 3. The principle of operation of an interferometer of this type is well known, but briefly:

Optical fibre output beam 4 is split into two by beam splitter 5; reference beam 6 propagates toward fixed mirror 7 and back toward the optical fibre; measurement beam 8 propagates toward movable mirror 9 and back toward the optical fibre. Beams 6 and 8 are combined to form interference fringes. These fringes are detected at detector 10 and counted to provide an indication of the distance moved by mirror 9 in the direction of arrows A.

It follows that in order to determine the displacement of mirror 9, the wavelength of the light used must be known. The more stable the frequency of this light the more accurate is the measurement of displacement.

Back-reflection is particularly problematic in this system because the laser is coupled to an optical fibre. In this system a normally problematic proportion of laser output light i.e. greater than 0.1% is back-reflected toward the laser resonant cavity. This back-reflected light comes from, for example, the

fibre entry, the sides of the fibre, the fibre exit, the fibre core, and a proportion of the light 6 and 8 reflected from mirrors 7 and 9.

5 Thus this apparatus demands stable frequency output at the laser and benefits from a gas laser having a high tolerance to back-reflections. In this instance the resonant cavity of the laser is filled with gas containing 80-90% He and 10-20% Ne. The Ne content is
10 a dual-isotope of Ne^{20} and Ne^{22} in substantially equal proportions i.e. any ratio between 60:40 and 40:60 respectively. This gas mixture allows back-reflected light levels in excess of 0.1% of the laser light output, without destabilisation of the output
15 polarisation. As a result of the polarisation stability, a stable frequency is obtainable also. Such back-reflections may occur continuously or at intervals. The laser achieves a frequency stabilisation below 1×10^{-7} (Frequency noise/Absolute
20 frequency) when an appropriate frequency control system is used.

Whilst many frequency control methods are known, the preferred method employed is modal control because it
25 was found to be reliable and cost effective. In this instance mode ratio control was used.

It has been noted by the inventor from experimental results that the back-reflection destabilisation
30 threshold (i.e. the level of back-reflected light at which a laser becomes unusably unstable) is approximately 10% of laser output for the above-mentioned laser but only about 1% for a conventional "natural" Ne laser i.e. a laser having a Ne^{20} to Ne^{22}

isotope ratio of approximately 9:1 respectively.

The inventor has found also that such a conventional laser with a "natural" (9:1) Ne isotope mix has a slightly better stability compared with the 1:1 Ne isotope mix laser when each is subjected to a back-reflection which is less than about 0.1% of laser light output. Consequently the 1:1 Ne²⁰ to Ne²² isotope mix has been found to be best suited to optical apparatus with a relatively high optical feedback i.e. greater than about 0.1% of laser light output.

Other applications of a laser of this type, within the ambit of this invention, are envisaged. For example, the linear laser described above might be used with spectroscopic analysis apparatus, polarisation measurement apparatus, or a heterodyne frequency measurement device each of which may benefit from a laser of the type mentioned above having a stable frequency output, particularly when back-reflections exceed approximately 0.1% of total laser output.

Stabilisation of the laser output frequency may be undertaken by any of the following known techniques:- the "Lamb Dip" technique; general intensity control; Zeeman frequency or intensity control; or modal control either balanced where the intensity of two modes is set to be equal or a ratio of modes, where the intensity ratio of the two modes is fixed.

CLAIMS

1. An optical apparatus comprising a frequency stabilised linear HeNe gas laser having an Ne content of an Ne^{20} isotope and an Ne^{22} isotope in substantially equal proportions, the apparatus in use having optical feedback toward the laser causing, at least 0.1% of the light output of the laser to be returned toward the laser.
2. An optical apparatus as claimed in claim 1 wherein the apparatus comprises one of:
 - an interferometric displacement determination device;
 - a polarisation measurement device;
 - spectroscopic analysis apparatus; or
 - a heterodyne frequency measurement device.
3. An interferometric displacement determination device comprising a frequency stabilised linear HeNe gas laser having an Ne content of an Ne^{20} isotope and an Ne^{22} isotope in substantially equal proportions, the apparatus in use having optical feedback toward the laser causing, at least at intervals, at least 0.1% of the light output of the laser to be returned toward the laser, the device being any one of a single beam, a plane mirror, a long range, or an optical fibre type.
4. An interferometric displacement determination device as claimed in claim 3 wherein the Ne^{20} and Ne^{22} isotope content is in the ratio of about 60:40 to about 40:60 respectively.
5. An interferometric displacement determination

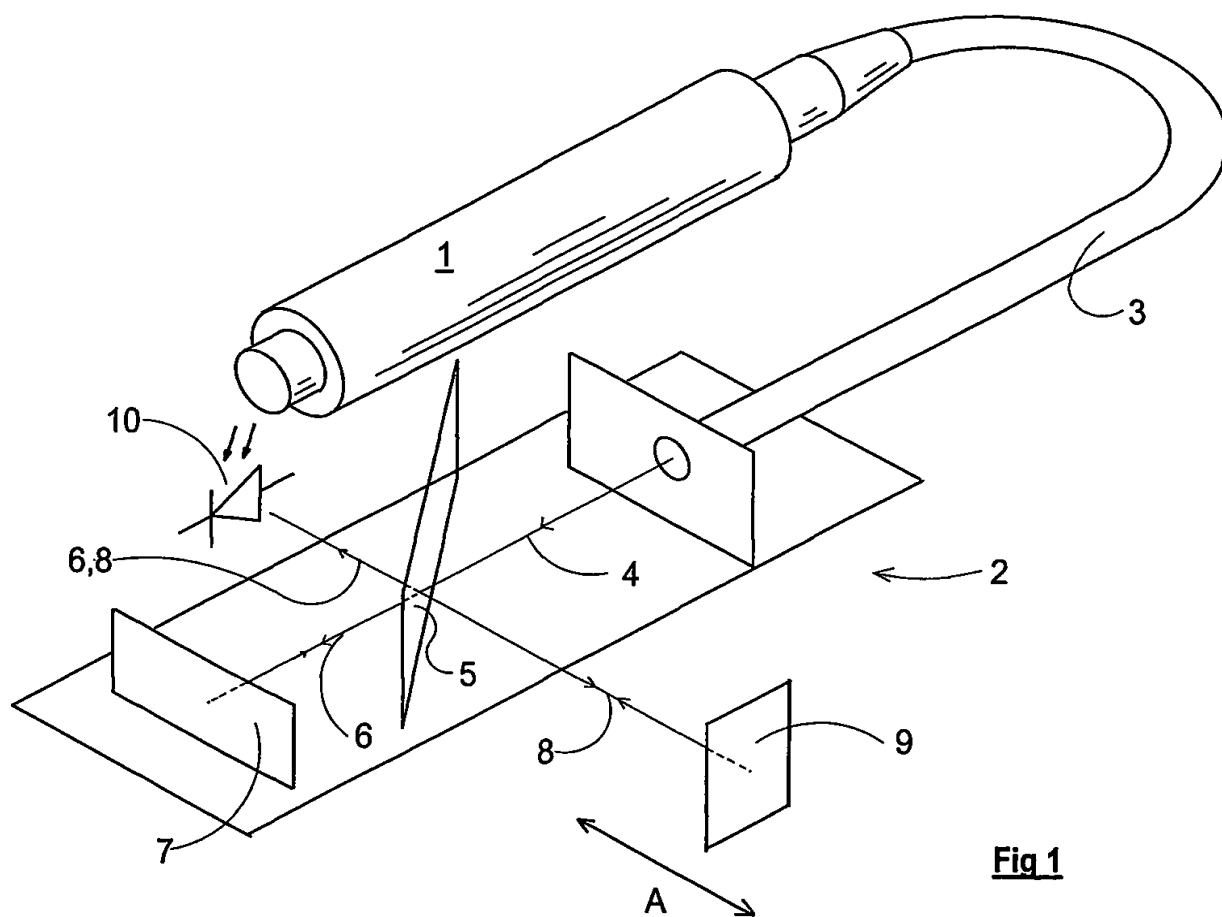
device as claimed in claim 3 or claim 4 wherein the HeNe gas ratio is about 80:20 to about 90:10 respectively.

5 6. An optical apparatus or interferometric displacement determination device as claimed in any one of the preceding claims wherein the laser achieves a frequency stabilisation below 1×10^{-7} (Frequency noise/Absolute frequency) and the optical feedback is
10 in the range of 0.1% to 10% of the light output of the laser.

7. An optical apparatus or interferometric displacement determination device as claimed in any one of the
15 preceding claims wherein the apparatus or the device includes an optical fibre element.

8. An optical apparatus or interferometric displacement determination device as claimed in claim 6
20 wherein the method of frequency stabilisation employed is modal control.

9. An optical apparatus or interferometric displacement determination device as claimed in claim 7
25 wherein the modal control is control of the ratio of the intensities of two laser modes.



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 01/02616

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01S3/22 H01S3/104

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CARTALEVA S ET AL: "Frequency tuning peculiarities of enhanced power monomode He-Ne lasers" OPTICAL AND QUANTUM ELECTRONICS, APRIL 1996, CHAPMAN & HALL, UK, vol. 28, no. 4, pages 395-403, XP001028580 ISSN: 0306-8919 the whole document -- --	1-9

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *G* document member of the same patent family

Date of the actual completion of the international search

27 September 2001

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/02616

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PETRU F ET AL: "SINGLE-FREQUENCY HENE LASER WITH A CENTRAL MAXIMUM OF OUTPUT POWER"</p> <p>OPTICS COMMUNICATIONS, NORTH-HOLLAND PUBLISHING CO. AMSTERDAM, NL, vol. 96, no. 4 / 5 / 6, 15 February 1993 (1993-02-15), pages 339-347, XP000336868 ISSN: 0030-4018 the whole document</p>	1,3
A	<p>US 4 844 593 A (PARKER DAVID R ET AL) 4 July 1989 (1989-07-04) cited in the application the whole document</p>	3-9
A	<p>CARTALEVA S ET AL: "Enhancement of single mode selection efficiency of He-Ne and He-Ne/I/sub 2/ lasers"</p> <p>1996 CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS DIGEST (CAT. NO.96CH35956), PROCEEDINGS OF 20TH BIENNIAL CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS, BRAUNSCHWEIG, GERMANY, 17-21 JUNE 1996, pages 104-105, XP002178650 1996, New York, NY, USA, IEEE, USA ISBN: 0-7803-3376-4 the whole document</p>	1,3
A	<p>SHAO XUE ET AL: "A new development in frequency stabilization of a longitudinal Zeeman laser"</p> <p>INTERNATIONAL CONFERENCE ON OPTOELECTRONIC SCIENCE AND ENGINEERING '90, BEIJING, CHINA, 22-25 AUG. 1990, vol. 1230, pages 400-402, XP001028581 Proceedings of the SPIE - The International Society for Optical Engineering, 1990, USA ISSN: 0277-786X the whole document</p>	1,9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 01/02616

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4844593	A	04-07-1989	CA 1321503 A1	24-08-1993
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			EP 0342885 A2	23-11-1989
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